GSJ: Volume 8, Issue 5, May 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

EFFECT OF PLASMA CARBURISING PROCESS ON ALUMINUM ALLOYS (AL-Cu 2118 SERIES)

Sujita Darmo[1], Rudy Sutanto[2]

[1,2]Faculty of Engineering, Departmen of Mechanical Engineering, Mataram University, Matara, Indonesia, 062-370-636126
E-mail: sujita@unramac.id

KeyWords
Plasma carburizing, aluminum alloys, focus shot, methane, surface hardness number,

ABSTRACT

In the present research a detailed effect of carbon-ions implantation in aluminum alloys (Al-Cu 2118 series) specimens at the room temperature by using a mathertype plasma focus device, operated with methane (a new process of plasma carburizing). Same treatment condition which has been reported in this study, fired at 15 kV giving a peak discharge current of about 150 kA over multiple focus shots. The results obtained indicates that the variation in focus shots has a significant impact on the surface hardness number of the Al-Cu 2118 series. The surface hardness number of the specimen increases continuously by increasing the ion content to 15 focus shots during the plasma carburizing process and reaches a maximum surface hardness number of 160 Kg.m^{-2}, which is almost six times compared to the surface hardness number of Al-Cu 2118 series which is untreated. Enhanced surface hardness can be associated with the formation of Al_4C_3 and amorphous carbon phases. Based on this investigation, a plasma carburizing device was found to be an efficient device to obtain a harder aluminum alloy surface in a room temperature
.

INTRODUCTION

Aluminum and its alloy like that Al-Cu 2118 series are popular for their extensive use in automotive piston, rail, marine and aerospace industries. It is widely used in electrical shielding, electronic circuits and devices making, food and pharmaceutical packaging, water treatment and house decoration owing to its nonmagnetic, very low sparking, less trashing, nontoxic and noncombustible behavior Febry et al., (2018) and Subbiah et al., (2018). It's outstanding properties of light weight, good malleability and formability, high corrosion resistance, excellent electrical and thermal conductivity, better light reflectivity and good recyclability are making the Al-Cu 2118 series an essential and ideal metal for today's advanced technological world. However, its insufficient wear resistance with low surface hardness number thermal and chemical stability limits its use for commercial and industrial purposes Li et al., (2019) and Pirizadh jrandoost et al., (2012) . The high surface hardness number and high strength to weight ratio of Al-Cu 2118 series for its application in the area of sliding machine parts for height saving purpose but its tensile strength and the low surface hardness (lower than that of mild steel and iron alloyed materials mainly used for these parts at present) offer a major barrier. Therefore surface modification of Al-Cu 2118 series, to improve wear and corrosion resistance, surface hardness and lower coefficient of friction, is intensively required to enhance its utilization in all fields of interest. Presently, nitriding, oxidizing and carburizing of aluminum by employing different techniques are commonly used to obtain tribologically and mechanically improved aluminium surface. Nitriding of aluminum is the most studied and investigated process for surface modification to achieve desired combination of physical and chemical properties. like high hardness, excellent wear resistance, high electrical and corrosion resistance, very good optical properties, and high thermal and chemical stability. For example Ghulam et al., (2009) , Patama et al., (2003) and Balanovski et al., (2017) reported that formation of hard aluminum nitride (AlN) layer on the surface can prolong the life time of aluminum. In spite of all the properties the Al-Cu 2118 series the surface of AlN layer is often morphologically rough containing deep grooves and cracks and is considered unsatisfactory for industrial application. Also the physical parameters' effects on tribological and mechanical properties of AlN are not yet well understood. Carburizing of aluminum however could provide a suitable alternative of nitriding for improved mechanical and tribological properties in a similar way as in the case of iron and steel Leyland et al., (2003) and Afza et al.,

(2019) .This inspired to study the ability of plasma focus for carburizing of Al-Cu 2118 series.

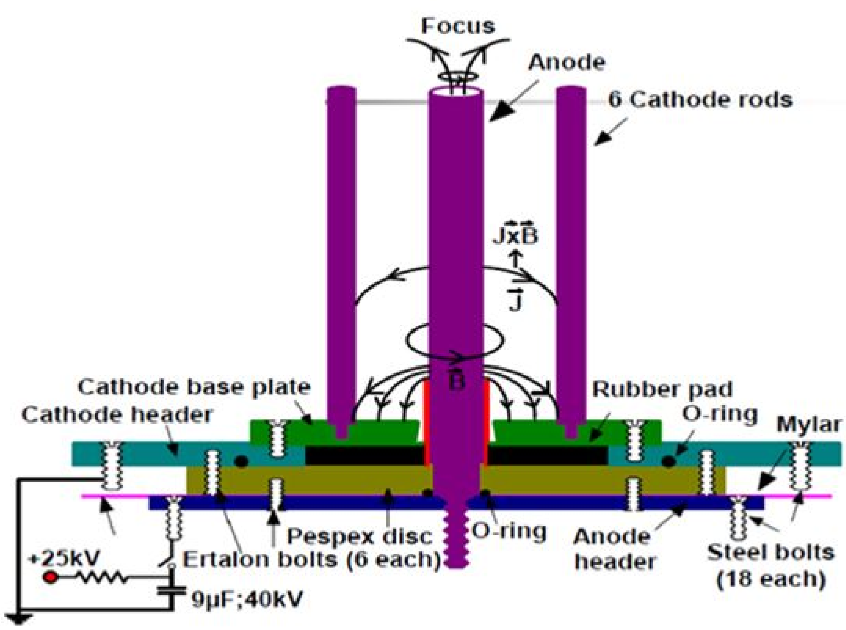
MATERIALS AND METHODS FOR EXPERIMENT

Aluminum alloys (Al-Cu 2118 series) specimens before treatment was tested by spectrometer with objective to understand consistence of material specification of Al-Cu 2118 series where standard ASTM can be seen in Table 1.

Table 1**.** Chemical Composition of Al-Cu 2118 series without treatment

Element	%
Si	0.01
Fe	0.1089
Cu	1.133
Mn	0.0162
Mg	1.8635
Zn	5.8113
Ti	0.0916
Cr	0.0916
Pb	0.0015
Sn	0.004
Al	90.75

The Plasma focus system consists of a coaxial electrode assembly with an anode of aluminium rod having an effective length of 100 mm and a diameter of 15 mm located at the centre surrounded by six equidistant symmetrical copper rods forming cathode with cathode to anode radius ratio of 3.5, shown in Figure 1. The anode is slightly tapered towards the open end to enhance the emission of charge particles. A Pyrex glass insulator sleeve of 23 mm breakdown length, with an external diameter of 24.5 mm and wall thickness of 2 mm, is used to separate the anode from the cathode base plate. A field distortion type spark gap is used to transfer energy from the capacitor bank to the electrodes of plasma focus system. The system is operated in a gas flow mode to get rid of the impurities.



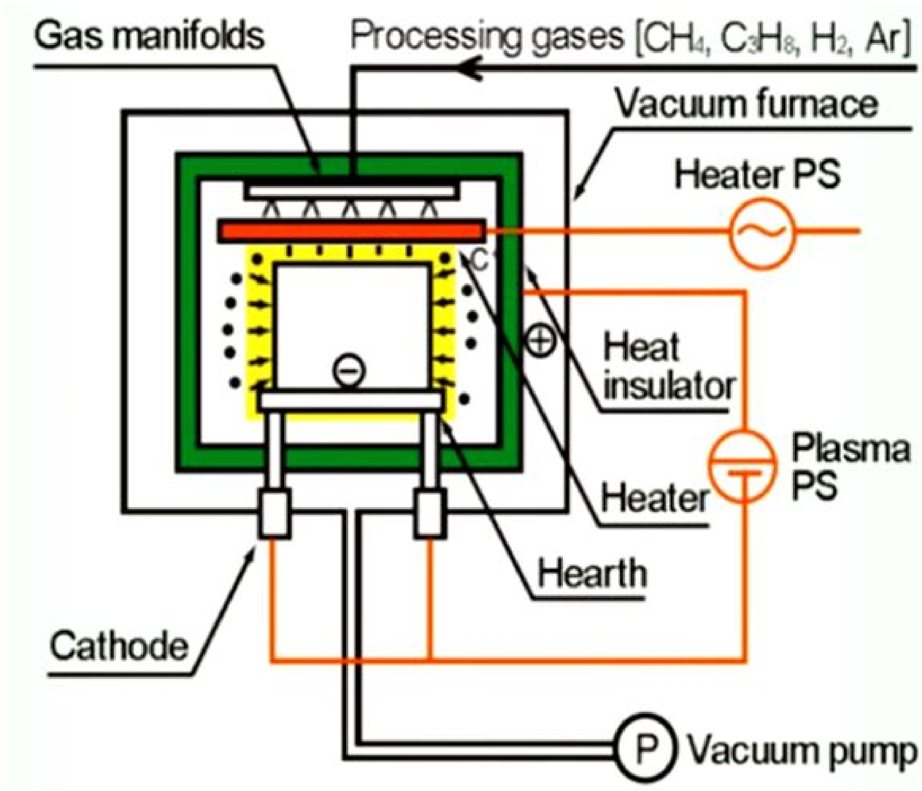


Figure 1. Plasma Carburizing Layout

RESULT AND DISCUSSION

Good carburizing plasma is obtained at a pressure of 0.5 mbar methane gas at a filling voltage of 15 kV. Optimal charging voltage and charging pressure values are kept constant during the experiment. 10 × 10 × 0.3 mm aluminum specimens are mechanically polished to the mirror surface before being positioned at an axial distance of 8 cm from the anode end. Al-Cu 2118 series aluminum alloys are placed between the ion sources which are used to avoid the effects of the ion beam emitted during conditioning shots. Rapid response photo conductive GaA detectors closed with 50 µm diameter pin holes are used at a distance of 8 cm in front of the anode end to measure the ionic energy emitted from plasma carburizing. The spatial distribution of the ion beam reaching the specimen is obtained by placing a CR-35 trace detector at a distance of 5 cm in front of the tip of the central anode. The performance of a plasma carburizing device with a sharp focus and energetic ion emissions is the most important in this type of experiment. Signals from GaA detectors, voltage probes, and Rogowski coils are continuously monitored with a Gould 3072 A oscilloscope with four-channel digital storage.

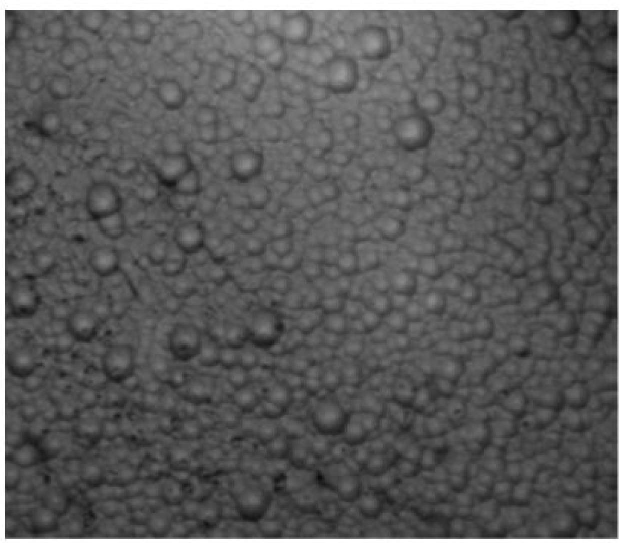


Figure 2. Al-Cu 2118 Series Surface Specimens After Plasma Carburizing Treatment

Furthermore, ion energy is generated around 25-250 keV. The trace on the surface of the specimen shown in figure 2. is the result of etching the detector for four hours in a dilute solution of 6N-NaOH at 75 oC. Based on Figure 2. it appears that the ion distribution is largely uniform. It can be observed that several ionic populations with different energy values also exist. Track density found varies from about 6×10^4 tracks mm^{-2} for directions 0 ° to 5×10^4 tracks mm^{-2} for directions ± 30 °.

.

Surface Hardness Number Results

The surface hardness as a function of the indentation depth is measured with Vickers micro hardness tester, as shown in the Figure 3. The loads 500 gr are applied to obtain micro hardness.

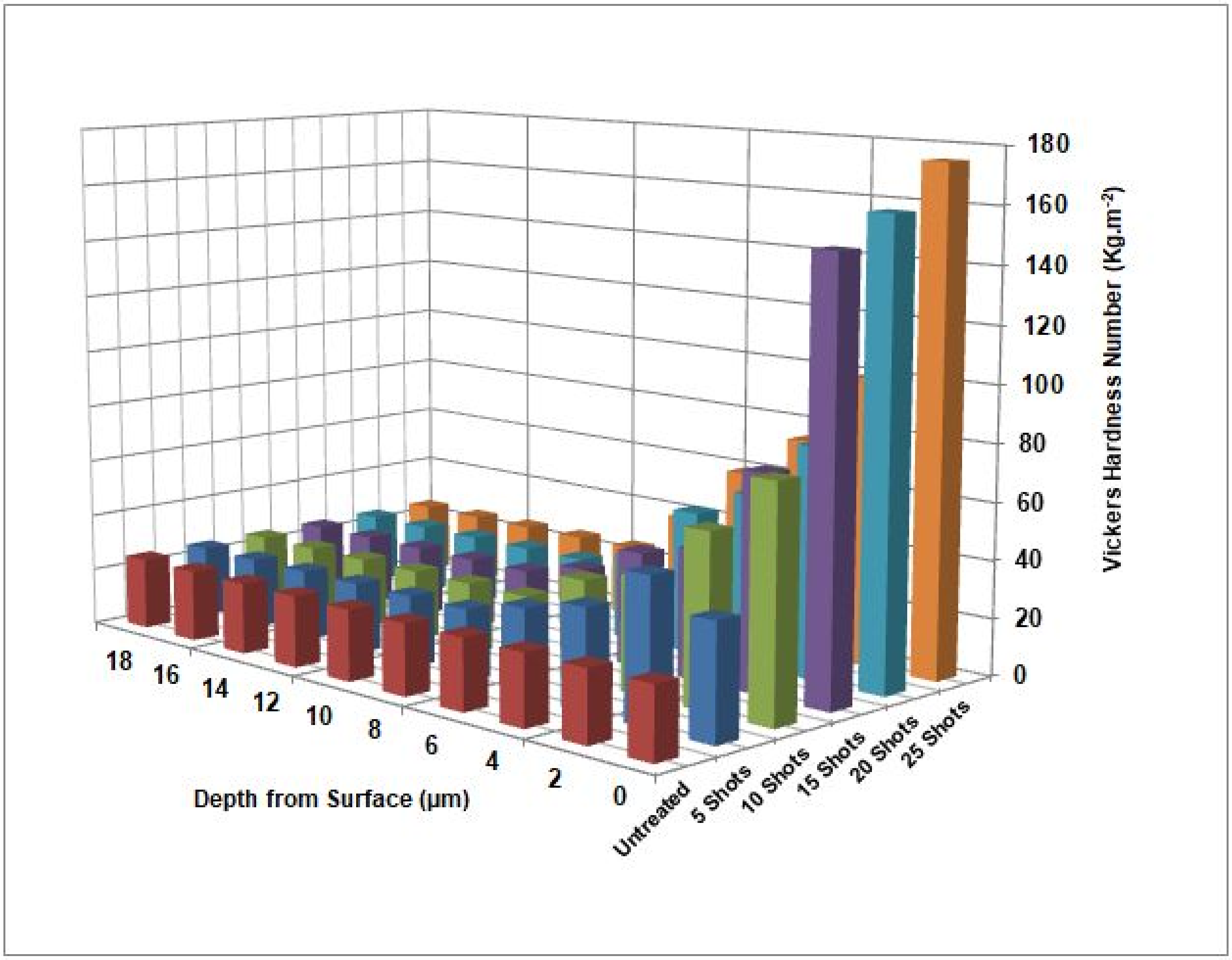


Figure 3. Surface Hardness Number Speciment with Plasma Carburizing

The surface hardness number of the specimen increases continuously by increasing the ion content to 15 focus shots during the plasma carburizing process and reaches a maximum surface hardness number of 160 $Kg.m^{-2}$, which is almost 6 times compared to the surface hardness number of Al-Cu 2118 series which is untreated. Enhanced surface hardness can be associated with the formation of Al_4C_3 and amorphous carbon phases. A slight decrease in surface hardness number occurs. When the sample is treated with more than 15 focus shots, a decrease in surface hardness number is observed. This may be caused by poor formation of the crystalline phase and damage to the carbide phase due to increased ion irradiation.

The Results of SEM Test

Figure 4. are the surface morphology of pristine and plasma carburized samples is studied by obtaining micrographs using a JEOL JSM-5910 scanning electron microscope (SEM). Based on observations, no significant features except the fine scratches induced by polishing are observed for a pristine sample. The surface smoothness seems to increase with increasing number of focus shots upto 15.It is assumed that upto 15 focus shots, in addition to Al4C3 phase and C-C clusters formation, the energy density of ions is

suitable to remove certain voids, asperities and rough particles by sputtering and etching processes and a smooth carburized surface is achieved. When the number of focus shots reaches to 20, surface layer becomes slightly rough with wavy wrinkle-like structure, which represents a thin superficially molten layer of the substrate. High doses of carbon and unbound carbon result in surface swelling of substrate increasing its roughness as in the case of nitriding. Surface treated with 25 focus shots shows rough surface and some micro-cracks with low density small pores. It is assumed that high fluencesof ion, generated by stable and strong focusing action, deliver excessive energy to substrate, causing sputtering and etching and hence resulted in surface damage and roughness along with a very few small pores. The quenching after the transient temperature rise with short pulse ion beam resulting in the brittleness of the sample may be the reason behind the development of micro cracks

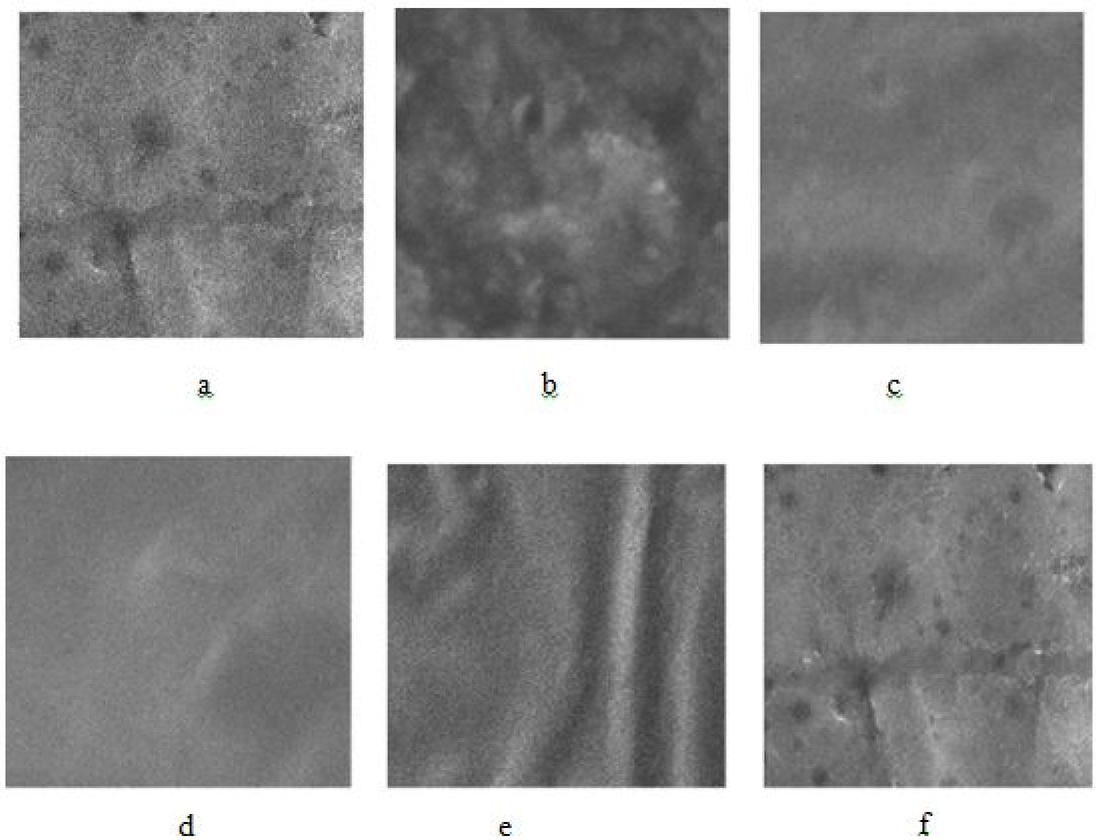


Figure 4. The Result of SEM Test Specimen with Plasma Carburizing. a.Untreated b. 5 Shots c. 10 Shot c. 15 Shot d.20 Shot

The variation of carbon and oxygen concentration with increasing number of focus shots is obtained by EDX attached with the SEM . The oxygen peak in the untreated sample is present because of native oxide layer. The concentration of oxygen is reduced by ion sputtering process with increasing number of focus shots but a negligible amount remains present. This may be due to re-oxidation of near surface region by residual gas and by the process of ion beam mixing. The concentration of carbon increases with increasing number of focus shots as expected.

CONCLUSIONS

The Plasma Carburizing process with methane using a plasma focus device Mathertype in a double focus shot can increase the surface hardness number of Al-Cu 2118 series. These results suggest the parameters for a plasma carburizing device to obtain a quality carburizing aluminum alloys surface. About six times the increase in surface hardness is caused by the hexagonal Al_4C_3 phase. Based on this investigation, a plasma carburizing device was found to be an efficient device to obtain a harder aluminum alloy surface in a room temperature environment and shorter time.

Acknowledgment

The authors thank Prof. Rudy Soenoko, Prof. Anindito are acknowledged for invaluable endless collaboration. Prof. I.G.NWardhana Director Postgraduated Doctor Mechanical Engineering Program Brawijaya University permission to use of laboratory and other resource materials.

References

[1] Afzal, Naveed & Rafique, Mohsin & Javaid, Wajeeha & Ahmad, Riaz & Farooq, Ameeq & Saleem, Murtaza & Khaliq, Zubair, Influence of Carbon Ion Implantation Energy on Aluminum Carbide Precipitation and Electrochemical Corrosion Resistance of Aluminum, Nuclear Instruments and Methods in *Physics Research Section B Beam Interactions With Materials and Atoms*, 2019, 436.pp. 84-91.

[2] Li, G. Meng, Liang, Y. Long, Yin, C. Hong, Sun, H., & Zhu, Z. Long, Study Of M50NIL Steel Under Carburizing and Nitriding Duplex Treatment. *Surface and Coatings Technology*, 2019, 375, pp.132–142. Https://Doi.Org/10.1016/J.Surfcoat.2019.07.017.

[3] Febri Budi Darsono, Teguh Triyono, And Eko Surojo, The Effect of Case Hardening Treatment on Aluminum 7075 Toward Its Hardness and Tensile Strength, *AIP Conference Proceedings 1931*, 030058, 2018, Https://Doi.Org/10.1063/1.5024117

[4] Yang, Y., Yan, M. F., Zhang, S. D., Guo, J. H., Jiang, S. S., & Li, D. Y. Diffusion Behavior Of Carbon And Its Hardening Effect On Plasma Carburized M50nil Steel: Influences Of Treatment Temperature And Duration, *Surface And Coatings Technology*, 2018, 333, pp.96–103. Https://Doi.Org/10.1016/J.Surfcoat.2017.10.068.

[5] Subbiah, R., & Pradeep, Y., The Wear Characteristics of AISI310 Grade Stainless Steel Material By Carburizing and Carbonitriding Process, *International Journal of Mechanical And Production Engineering Research And Development*, 2018, 8(6), 159–164. Https://Doi.Org/10.24247/Ijmperd dec 201818.

[6] Sugawara, Yu & Inoue, Waka & Muto, Izumi & Hara, Nobuyoshi, A Methodology For Fabrication Of Highly Pitting Corrosion-Resistant Type 304 Stainless Steel By Plasma Carburizing And Post-Pickling Treatment, *Journal Of The Electrochemical Society*, 2018, 165. C441-C449. 10.1149/2.0081809jes.

[7] Balanovskii, A & Grechneva, M & Huy, Vu & Zhuravlev, D., New Plasma Carburizing Method. *Iop Conference Series: Earth And Environmental Science*, . 2017, 87. 092003. 10.1088/1755-1315/87/9/09 2003.

[8] Pirizadhejrandoost, Somayeh & Bakhshzad Mahmoudi, Mehdi & Ahmadi, Elnaz & Moradshahi, Masoud, The Corrosion Behavior Of Carburized Aluminum Using Dc Plasma. *Journal Of Metallurgy*, 2012, 2012. 10.1155/2012/258021.

[9] Kula, P., Pietrasik, R., & Dybowski, K., Vacuum Carburizing Process Optimization, *Journal Of Materials Processing Technology*, 2005, 164–165, 876–881. Https://Doi.Org/10.1016/J.Jmatprotec.2005.02.145.

[10] Ghulam Murtaza, S.S. Hussain, Mehboob Sadiq, M. Zakaullah, 2009, Plasma Focus Assisted Carburizing Of Aluminium, *Thin Solid Films*, 2009, Volume 517, Issue 24, pp.6777-6783, Issn 0040-6090, Https://Doi.Org/10.1016/J.Tsf.2009.05.065. (Http://Www.Sciencedirect.Com/Science/Article/Pii/S0040609009010153).

[11] Patama Visuttipitukul, , Tatsuhiko Aizawa And Hideyuki Kuwahara, Advanced Plasma Nitriding For Aluminum And Aluminum Alloys, *Materials Transactions*, 2003, Vol. 44, No. 12 (2003) Pp. 2695 To 2700

[12] Leyland, A., Lewis, D. B., Stevensom, P. R., & Matthews, A. (1993). Low Temperature Plasma Diffusion Treatment Of Stainless Steels For Improved Wear Resistance. Surface And Coatings Technology, 62(1–3), 608–617. Https://Doi.Org/10.1016/0257-8972(93)90307-A.

[13] Samandi, M., Shedden, B. A., Smith, D. I., Collins, G. A., Hutchings, R., & Tendys, J., Microstructure, Corrosion And Tribological Behaviour of Plasma Immersion Ion Implanted Austenitic Stainless Steel. *Surface And Coatings Technology*, 1993. 59(1–3), 261–266. Https://Doi.Org/10.1016/0257-8972(93)90094-5.